APPLICATION FOR UNITED STATES PATENT

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Invention Title: *PUMP PULSATION DAMPENING ATTACHMENT AND METHOD FOR DAMPENING PUMP PULSATIONS*

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PUMP PULSATION DAMPENING ATTACHMENT AND METHOD FOR DAMPENING PUMP PULSATIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates generally to a pump delivery system adaptable to dampen the pulsating flow or hydraulic shock caused as result of the intermittent nature or the idle period of the pump mechanism and also adaptable for use in sanitary filling operations. More particularly, the invention relates to a hydraulic shock absorbing attachment adaptable to substantially dampen pulsations resulting from the operation of various pumps including constant pressure pumps for the high-speed delivery of precisely measurable quantities of liquids.

2. Description of the Related Art

[0002] A wide variety of industrial applications, especially in the pharmaceutical and food processing industries require high-speed fluid metering and pumping systems capable of delivering precisely measured quantities of fluids at accurate flow rates to various locations. Sanitary filling operations require that sanitary pumping systems provide a constant pressure in order to deliver precise quantities of liquid food products of varying consistencies, viscosities, densities, etc. such as milk, yogurt,

cream, cream cheese, etc. to fill heads for the subsequent metered dispensation into containers. Such sanitary pump systems are adapted to operate under high speed pumping operations in pressure ranges of 400 pounds per square inch (psi) or greater and pumping cycles in the range of about 20-200 cycles per minute and preferably 60-160 cycles per minute to provide constant flow. Accordingly, in such operations, precise and accurate fluid delivery is critical.

[0003] Moreover, such sanitary filling operations must meet the performance requirements established by the U.S. Food and Drug Administration (FDA), which require that machines used to fill containers with liquid food or drug products must be sterilizable, and readily cleaned of liquid products which might be trapped in cavities within machine parts, and thereby providing a growth media for microbes. Accordingly, a goal in the design and construction of production line filling machines for liquid food products is that to provide an attachment as well as components suitable for Cleaning-In-Place (C.I.P.), with no or minimal disassembly of machine components required.

[0004] Heretofore, pump delivery systems for pumping fluids to various sources, are known in the art. Many of such prior art systems utilize various pump mechanisms to carry out the delivery operations, such as piston pumps, diaphragm pumps, positive displacement pumps, centrifugal pumps and the like. Prior art systems of the aforementioned

types typically deliver such fluids under constant pressure in an effort to achieve consistent flow rates. While these prior art systems are sometimes adequate for certain applications, precise and accurate flow rates in such systems are difficult to achieve due to the pulsing, surging, or hydraulic shock generated by the output of the pump mechanism, which also must be comparable with CIP facilities. For example, positive displacement pumps typically generate significant pressure surges due to the rapid acceleration and deceleration of the liquid during the sinusoidal cycle of the pump. Such pulsing, surging or otherwise hydraulic shock is undesirable since it typically results in hydraulic hammer in process lines, large pressure fluctuations, excessive wear and increased cost of maintenance of pumps and instruments, inaccurate flow rates during delivery operations, which results in increased production costs production time.

[0005] Many prior art pump delivery systems have attempted to dampen, suppress, reduce or otherwise minimize the surging or pulsing output generated by the associated pump mechanism during delivery operations. For example, U.S. Patent No. 5,806,716 to Vogt provides a pressurized tank that offers high speed, mass production filling of containers with a mass flow sensor mounted on a means for dampening vibration to ensure accurate measurement of dispensed fluids. The pressurized tank includes pressures regulators sensors and a computer for

controlling its operation. The pressurized tank of Vogt, however, is not adaptable for standard pumps with mechanical pumps such as cylinders, as they are found to be unsuitable since they permit the occurrence of undesirable contaminates. Accordingly, the tank in Vogt cannot accommodate a wide range of pumps and pumping systems in which pump pulsating output is variable. The tank also lacks a sensing mechanism for monitoring and adjusting the air-to-liquid ratio in the dampening chamber and is not sized to correspond to the duration and intensity level of the pulsating output.

[0006] U.S. Patent No. 5,730,324 to Shannon et al. provides a post-mixed beverage dispensing system from a pressurized tank that is pressurized by a pressurized tank pump. In order to overcome the problems of the reduction of pressure associated with the simultaneous multiple dispensing and/or rapid sequential dispensing operations, the pressurized tank is maintained at a constant pressure by pumping syrup into the tank and venting the tank in order to prevent over-pressurization. The tank of Shannon, however, does not include a sensing mechanism for monitoring and adjusting the air-to-liquid ratio in the dampening chamber and is not sized to correspond to the duration and intensity level of the pulsating output. The tank is also not adaptable for use in combination with a wide range of pumps and pumping systems in which pump pulsating output is variable.

[0007] U.S. Patent No. 5,639,219 to Conatser provides a paint sprayer that employs a dampener in the form of a T-shaped fitting having a volume dampening chamber with a trapped volume of air which dampens the acceleration/deceleration forces and acceleration spikes transmitted from the pump to the delivery fluid. Conatser, however, does not include CIP or a sensing mechanism for monitoring and adjusting the air-to-liquid ratio in the dampening chamber.

[0008] U.S. Patent No. 2,764,103 to Mercier discloses a pulsation dampener for a pump mechanism that reduces the effects of pumping pulsation whereby a deformable rubber bladder encased in a pressure accumulator to suppress pump pressure surges. The accumulator includes a valve for pressurizing a gas inside the bladder to suppress the pump spikes resulting from the operation of the pump piston. Mercier, however, lacks CIP or probes or sensing devices for accommodating the ratio between the air and liquid.

[0009] Heretofore, none of the aforementioned prior art systems are equipped for high pressure and high-speed fluid metering and pumping (i.e., pressure ranges of 400 pounds psi or greater and pumping cycles in the range of about 20-200 cycles per minute and preferably 60-160 cycles per minute) in delivering precise measured quantities of fluids at accurate flow rates. Many prior art systems are also not adaptable for use in sanitary filling operations since they lack a pump pulsation dampening

assembly that also meets the cleaning-in-place standards required by the FDA. The prior art also fails to provide an attachment for accommodating a wide range of pumps and pumping systems or a method of dampening pulsations resulting from the operation of various pumps. The prior art also lacks a device that monitors and adjusts the air-to-liquid ratio inside a pump pulsation dampening attachment in response to the duration and intensity of the pulsating fluid flow.

SUMMARY OF THE INVENTION

[0010] Accordingly, it is an object of the invention to provide a pump delivery system that is adaptable for a variety of sanitary filling operations.

[0011] It is another object of the invention to provide such a pump delivery system that is adaptable for high-pressure and high-speed capacity pumping operations.

[0012] It is an additional object of the invention to provide such a pump delivery system adapted for use with a variety of pump mechanisms.

[0013] It is a further object of the invention to provide such a pump delivery system that facilitates the efficient delivery of fluids by providing a pump pulsation dampening attachment that dampens the pulsating flow output generated by the pump mechanism.

[0014] It is yet another object of the invention to provide such a pump delivery system adaptable to monitor and adjust the air-to-liquid ratio inside

a pump pulsation dampening attachment in response to the duration and intensity of the pulsating fluid flow.

[0015] It is still another object the invention to provide such a pump delivery system that facilitates effective cleaning-in-place (CIP).

[0016] In accordance with these objects and the principles of the invention, provided herein is a pump delivery system including a pump mechanism for delivering a liquid under pressure and which generates a pulsating output during operation, and a pump pulsation dampening assembly for substantially reducing the pulsating output of the pump mechanism. In accordance with this aspect of the invention, the pump pulsation dampening assembly includes a pressurized vessel having an interior surface defining a chamber for receiving the liquid from the pump mechanism, the chamber also containing a pocket of pressurized air therein for absorbing the pulsating output generated by the pump mechanism; a sensing mechanism for monitoring the air-to-liquid ratio inside the chamber, the sensing mechanism being adaptable for producing an output signal in response thereto; and an adjustment mechanism in communication with the sensing mechanism and adapted to receive the output signal from the sensing mechanism and to provide an adjustment to the air-to-liquid ratio inside the chamber to a desired level in response thereto.

[0017] The invention is also directed to a pump delivery system including a pump mechanism for delivering a liquid under pressure, the pump mechanism also generating a pulsating output during operation, and a pump pulsation dampening assembly for dampening the pulsating output of the pump mechanism. In accordance with this aspect of the invention, the pump pulsation dampening assembly includes a pressurized vessel having an interior surface defining a chamber for receiving the liquid, the chamber also containing a pocket of pressurized air therein for absorbing the pulsating output, the chamber being sized to correspond to the duration and intensity level of the pulsating output.

[0018] The invention is further directed to a pump pulsation dampening attachment including a pressurized vessel having an interior surface defining a chamber for receiving a liquid, the chamber containing a pocket of air therein for absorbing pulsating fluid flow; and a sensing mechanism for monitoring and adjusting the air-to-liquid ratio inside the chamber in response to the duration and intensity of the pulsating fluid flow.

[0019] The invention is also directed to a pump pulsation dampening attachment comprising a pressurized vessel having an inlet end for receiving a liquid, an outlet end for dispensing the liquid, an interior surface defining a chamber for containing the liquid, the chamber also containing a pocket of air therein for absorbing pulsating flow of the liquid, and a control

end for controlling the air-to-liquid ratio inside the chamber in response to the duration and intensity of the pulsating fluid flow.

[0020] The invention is even further directed to a pump delivery system adapted for use in a sanitary filling operation, the pump delivery system including a pump mechanism that generates a pulsating output when delivering a liquid under pressure to a filling machine, the pump mechanism having an inlet port for receiving the liquid and an outlet port in communication with the filling machine for transporting the liquid thereto; and a pump pulsation dampening assembly for dampening the pulsating output of the pump mechanism, the pump pulsation dampening assembly disposed in communication with the outlet port and in communication with the filling machine. In accordance with this aspect of the invention, the pump pulsation dampening assembly includes a pressurized vessel having an inlet port for receiving the liquid from the outlet of the pump mechanism, an outlet port for permitting a flow of the liquid into the filling machine, and an interior surface defining a chamber for containing and receiving a volume of the liquid from the pump mechanism, the chamber also containing a pocket of pressurized air therein for absorbing the pulsating output generated by the pump mechanism, a sensing mechanism for monitoring the air-to-liquid ratio inside the chamber, the sensing mechanism being adaptable for producing an output signal in response thereto, an adjustment mechanism in communication with the chamber for

providing an adjustment to the air-to-liquid ratio inside the chamber to a desired level in response to the output signal produced by the sensing mechanism, a sanitary cleaning mechanism for cleaning-in-place the interior surface of the pressurized vessel, and a supplemental dampener and pulse rate indicator in communication with the pressurized vessel for absorbing at least a portion of the pulsating output generated by the pump mechanism and also serving as a visual indicator of the pulsation rate of the pump mechanism.

[0021] The invention is also directed to a method of dampening pulsations associated with a pump mechanism which generates a pulsating output during operation, the method including the steps of utilizing a pressurized vessel having an interior surface defining a chamber for receiving a certain volume of the liquid from the pump mechanism, the chamber containing a pocket of pressurized air therein; sizing the volumetric capacity of the chamber in response to the duration and intensity level of the pulsating output; employing a supplemental dampener and pulse rate indicator in communication with the pressurized vessel; absorbing the pulsating output using the pocket of pressurized air; supplementing the absorbing step by absorbing at least a portion of the pulsating output using the supplemental dampener and pulse rate indicator; and observing the pulse rate of the pump mechanism using the supplemental dampener and pulse rate indicator.

[0022] Accordingly, the pump delivery system in accordance with the invention is advantageous in being adaptable to quickly and efficiently deliver fluids by minimizing flow pulsations caused by the pulsing output of the pump mechanism. The pump delivery system is also advantageous in reducing manufacturing costs and increasing production. The pump delivery system is further advantageous in providing a system that meets FDA standards in facilitating the cleaning-in-place of the interior surface of the pressurized vessel.

[0023] Moreover, the pump delivery system in accordance with the invention may be used not only for sanitary operations but all high-speed capacity pumping operations, particularly where constant pressure is desired. In this regard, the pump delivery system is adaptable for various pump mechanisms, particularly those that are adapted for high-speed operations that require constant pressure.

[0024] These and other objects, features and advantages of the invention will become more apparent from the following description when taken in conjunction with the detailed drawings that show, for purposes of illustration only, the preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The advantages of the invention will become more apparent to those skilled in the art in conjunction with the detailed description of the preferred embodiments of the invention, in which:

[0026] FIG. 1 is a side elevational view partly in section of the novel pump delivery system adapted for use in a sanitary filling operation;

[0027] FIG. 2 is a side elevational view partly in section of the pump pulsation dampening attachment equipped with a sanitary cleaning mechanism for cleaning-in-place the interior surface of the pressurized vessel;

[0028] FIG. 3 is a side elevational view partly in section of the novel pump delivery system adaptable for a diaphragm pump;

[0029] FIG. 4 is a side elevational view partly in section of the pump pulsation dampening attachment equipped with a sanitary cleaning mechanism for cleaning-in-place the interior surface of the pressurized vessel;

[0030] FIG. 5 is a side elevational view partly in section of the novel pump delivery system adaptable for a centrifugal pump;

[0031] FIG. 6 is a side elevational view partly in section of the novel pump delivery system adapted for use in a sanitary filling operation in accordance with another embodiment of the invention, the system including a supplemental dampener and pulse rate indicator for absorbing

at least a portion of the pulsating output generated by the pump mechanism;

[0032] FIG. 7 is a side elevational view partly in section of the pump pulsation dampening attachment in accordance with another embodiment of the invention, whereby the pump pulsation dampening assembly is equipped with a sanitary cleaning mechanism and a supplemental dampener and pulse rate indicator;

[0033] FIG. 8 is a side elevational view partly in section of the novel pump delivery system adaptable for a diaphragm pump;

[0034] FIG. 9 is a side elevational view partly in section of the pump pulsation dampening assembly in accordance with another embodiment of the invention, whereby the pump pulsation dampening attachment is equipped with a sanitary cleaning mechanism and a supplemental dampener and pulse rate indicator;

[0035] FIG. 10 is a side elevational view partly in section of the novel pump delivery system adaptable for a positive displacement pump;

[0036] FIG. 11 is a front elevational view partly in section illustrating the pump pulsation dampening attachment in accordance with another embodiment of the invention, whereby the pressure vessel is configured for pump mechanisms that produce low-intensity pulsations;

[0037] FIG. 12 is a front elevational view partly in section illustrating the pump pulsation dampening attachment shown in FIG. 9 having a pump delivery system adaptable for a diaphragm pump; and

[0038] FIG. 13 is a side elevational view partly in section of the novel pump delivery system that employs a double acting piston pump and a pressure vessel whereby the pressure vessel is configured for pump mechanisms that produce low-intensity pulsations.

DETAILED DESCRIPTION OF THE INVENTION

[0039] As shown in FIG. 1, in a first embodiment of the invention, a pump delivery system 10 adapted for use in a sanitary filling operation that includes a filling machine 140 whereby a viscous fluid or liquid (L) is delivered to a fluid manifold 150 in communication with a plurality of fill heads 160 which dispense the fluid to respective containers (not shown).

[0040] As shown in FIGs. 1, 6, 8 and 13, the pump delivery system 10 of the invention includes a pump mechanism 20 mechanically driven by a motor 30 for delivering the liquid (L) under pressure to the filling machine 140, the pump mechanism 20 generating a pulsating output during operation. As shown in FIGs. 1 and 11, the pump mechanism 10 may include a double acting piston head 21 driven by a drive shaft 22 having a pair of inlet ports 23, 24 for receiving the liquid (L) and a pair of outlet ports 40, 41 in communication with a pump pulsation dampening attachment or

assembly 50 for transporting the liquid (L) thereto. As illustrated in FIG. 6, each embodiment of the invention may be provided with a mass flow sensor 42, preferably of any type known in the art.

[0041] As illustrated in FIGs. 3, 5, 10 and 12, the pump delivery system 10 is not limited to the pump mechanism embodied in FIGs. 1, 6, 8 and 13, and are adaptable for a wide-variety of pump mechanisms 20, such as, but not limited to, diaphragm pumps, centrifugal pumps, and positive displacement pumps, etc. The pump delivery system 10 is also adaptable for pumps that are capable of achieving high-pressure rates, e.g., pressure ranges of 400 pounds psi or greater and pumping cycles in the range of about 20-200 cycles per minute and preferably 60-160 cycles per minute.

[0042] The pump pulsation dampening assembly 50 is provided for substantially dampening the pulsating flow output generated by the pump mechanism 20, and is disposed in series with the sanitary pump mechanism 20 and the filling machine 140. In particular, the pump pulsation dampening assembly 50 is disposed in the fluid flow path downstream of the pump mechanism 20 and upstream of the final dispensing destination, in this example, the filling machine 140.

[0043] The pump pulsation dampening assembly 50 includes a generally cylindrical pressurized vessel 60 having a sealed inlet port 61 for receiving the liquid (L) from the outlets 40, 41 of the pump mechanism 20,

a sealed outlet port 62 for permitting a flow of the liquid (L) into the filling machine 140, and a control end that includes pressure regulator 70, over pressure relief valve 80, sensing mechanism 90, supplemental dampener/pulse rate indicator 100 and sanitary cleaning mechanism 110. A control valve 64 is provided to permit the transfer of the liquid (L) into the fluid manifold 150 while prevented the back flow of the liquid into the vessel 60. It is preferred that the vessel 60 and all components associated therewith is composed of self-lubricating, abrasive-resistant, rust-resistant and hygienic materials. Most preferably, a material such as stainless steel is utilized to form the vessel 60.

[0044] The vessel 60 also has an interior surface defining a chamber 63 for receiving a volume of liquid (L) from the pump mechanism 20, the chamber 63 also having a volume of pressurized air, i.e., an air pocket (A) therein for absorbing the pulsating fluid flow output generated by the pump mechanism 20, and thereby maintain constant fluid flow during delivery operations. Accordingly, the air pocket (A) inside the chamber 63 behaves as a cushion in absorbing the pulsating flow. Because the intensity level of the pulsations vary between different pump mechanisms, the size of the vessel 60, specifically, the volumetric capacity of the chamber 63, should correspond to the type of pump mechanism 20 utilized in the pump delivery system 10. For instance, because centrifugal pumps cause low intensity pulsations, the volumetric capacity of the chamber 63 should

correspondingly be low since less dampening is required. On the other hand, reciprocating pumps generate high intensity pulsations, a chamber 63 having a large volumetric capacity should be used. Accordingly, the pump delivery system 10 of the invention accommodates for the wide-range of pulsation intensities associated with different pumps by providing vessels 60 with chambers 63 of varying volumetric capacities. For instance, the vessels 60 shown in FIGs. 1-8 have chambers 63 of generally large volumetric capacities while the vessels shown in FIGs. 9-13 have chambers 63 of generally smaller volumetric capacities.

[0045] Moreover, the desired liquid-to-air ratio provided in the chamber 63 may change depending upon the requirements of the delivery operations, which may take into account, the different types of pump mechanisms 20 utilized, changes in the liquid viscosity and liquid density, and other factors such as temperature, humidity, etc.

[0046] The vessel 60 is sealingly provided with a sensing mechanism 90 for monitoring the air-to-liquid ratio and/or pressure inside the chamber 63, said sensing mechanism 60 being adaptable to produce or otherwise transmit an electronic output signal in response thereto. The sensing mechanism 90 includes a main body 92 with an elongated tube or probe 91 fixedly extended therefrom. During a delivery operation, if the level of the liquid (L) reaches a height so as to contact the distal end of the probe 91, thereby indicating an impermissible air-to-liquid ratio inside the

chamber 63, the sensing mechanism 90 transmits the output signal to the adjustment mechanism 93. Alternatively, the probe 91 may also be equipped with a transducer to enable sensing of the pressure level inside the chamber 63, and in turn transmit a signal to the adjustment mechanism 93 in response to the sensing of an undesirable pressure level. While the drawing figures illustrate the use of a single probe 91, it is apparent to those skilled in the art that the sensing mechanism 90 may employ a plurality of probes 91 to sense the fluid level, the air-to-liquid ratio and/or the pressure inside of the chamber 63. Moreover, the probe 91 may alternatively be adaptable to reciprocate telescopically along its vertical axis to extend further into the chamber 63.

[0047] As illustrated in FIGs. 2, 4, 7, and 9-13, the adjustment mechanism 93 is in sealing communication with the chamber 63 and includes an air source (not shown) and a receiver configured to receive the output signal from the sensing mechanism 90. In response to an indication of an increase in the fluid level, or an otherwise reduction in the air-to-liquid ratio, the adjustment mechanism 93 automatically adjusts the air pressure in the chamber 63 by providing a volumetric increase of air inside therein to a desirable level. To minimize parts of the overall assembly, the sensing mechanism 90 and the adjustment mechanism 93 may be combined to form a single unit that accomplishes the tasks of sensing the fluid, air-to-

liquid ratio and/or air pressure in the chamber 63 and making the necessary adjustments in response thereto.

[0048] The pressure regulator 70 and over-pressure relief valve 80 are sealingly disposed in communication with the chamber 63. The pressure regulator 70 may be of any type known in the art that is configured to perform within the range of pressures for which is required, and may also have a sanitary design compatible with pharmaceutical or food applications. The over pressure relief valve 80 may be of any type known in the art that is configured to discharge air when the pressure exceeds a desired or permissible level and may also have a sanitary design compatible with pharmaceutical or food applications.

[0049] As illustrated in FIGs. 2, 4, 7, 9, 11 and 13, for those applications that require the sanitary filling of liquids (L) into containers, the vessel 60 preferably includes a sanitary cleaning mechanism 110 for cleaning-in-place (CIP) the interior surface of the pressurized vessel 60. The sanitary cleaning mechanism 110 includes a conduit 120 having an inlet port for receiving a volume of sanitized fluid from a sanitized fluid source (not shown) and an outlet port disposed inside the chamber 63 for dispensing a sufficient volume of sanitized fluid to facilitate the CIP operation. The outlet port may be provided with a generally circular nozzle head 130 having a plurality of apertures for spraying the sanitized fluid into the chamber 63 and on the interior surface of the vessel 60. The nozzle

head 130 may have any geometric shape that permits the effective spraying of sanitizing fluid during a CIP operation. In this regard, the conduit 120 and nozzle head 130 should preferably have sanitary designs that are compatible with pharmaceutical or food applications.

[0050] As illustrated in FIGs. 4-7, in order to provide an even effective manner of dampening pump output pulsations during a delivery operation, each embodiment of the pump delivery system 10 may further include a supplemental dampener/pulse rate indicator 100 that is placed in communication with the pressurized vessel and which absorbs at least a portion of the pulsating output generated by the pump mechanism 20. The supplemental dampener/pulse rate indicator 100 includes a expandable vessel 101 having an interior chamber in direct fluid communication with the vessel chamber 63 to thereby expand and contract (see hatched lines) in response to the pulsating action of the pump mechanism 20. As an added safety feature to contain the possible event of the expandable vessel 101 going beyond its elastic capacity, the expandable vessel 101 is sealingly enclosed in an expandable container 102. It is especially preferred that the container 102 is composed of a clear translucent material to permit the expandable vessel 101 to be seen by the eye. Such a feature is advantageous in permitting the supplemental dampener/pulse rate indicator 100 to also serve as a visual indicator of the pulse rate of the output from the pump mechanism 20. It is preferable that the expandable

vessel 101 is composed of a deformable material having mechanical memory that allows the expandable vessel 100 to maintain its form even in occurrences of large pulsations. It is even more preferable that the deformable material comprises rubber.

[0051] As illustrated in FIG. 9, the supplemental dampener/pulse rate indicator 100 may further include a pair of expandable vessels including an inner vessel 101 in direct communication with the chamber 63 and an outer vessel 103 that surrounds the inner vessel 101 to simultaneously expand an contract in relation to the pulsation output from the pump mechanism 20. It is preferable that each expandable vessel 101, 103 is composed of the same deformable material having mechanical memory. It is even more preferable that the deformable material comprises rubber. It is even more preferred that the rubber used for the inner vessel 101 is of a dark color while the rubber used for the outer vessel 103 is of a clear, translucent type to permit an enhanced visualization of the pulsing action.

[0052] The pump pulsation dampening assembly 50 operates by absorbing a volume of the liquid (L) during the discharge cycle of the pump 20, while on the suction cycle of the pump cycle, the air inside the dampening mechanism 100 is forced, resulting in essentially smooth flow, thereby enabling the liquid (L) to continue moving rather than accelerating, decelerating, and stopping.

[0053] Accordingly, the invention is advantageous in providing a pressure delivery system adapted to automatically reduce, minimize, suppress or otherwise dampen undesirable pulsating outputs from the delivery pump, which results in consistent flow rates during fluid delivery, which has the added benefit of reducing production costs and increasing manufacturing output.

[0054] The invention is also advantageous in providing such a pump delivery system that is adaptable for high-speed capacity pumping operations where constant pressure is desired. The invention is even further advantageous in providing such a pump delivery system that is adaptable for sanitary filling operations, especially those requiring CIP. The invention is still further advantageous by varying the volumetric capacity of the vessel chamber in response to the pulsation differences between pump mechanisms.

[0055] It is apparent that innumerable variations of the preferred embodiments described hereinbefore may be utilized. However, all such variations within the spirit and scope of the invention are deemed to be covered by the claims.